Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 83 (2014) 462 – 468
Procedia Engineering
www.elsevier.com/locate/procedia

“SYMPHOS 2013”, 2nd International Symposium on Innovation and Technology in the Phosphate Industry

# Project Management Procedures Needed to Design the Newest Four Phosphoric Acid Evaporators in North America

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**Abstract**

This paper presents the project management techniques needed to design the newest four evaporators installed in North America, and any similar project. The four evaporators included integral fluosilicic acid recovery systems, and were successfully designed, fabricated, erected and operational by mid 2009. Topics discussed in the paper include: Project Objectives, Project Stages, Scope Definition, Design Basis, Codes and Standards, Technology Selection, Capital Cost Estimation, Schedule Development and Control, Operating Cost Estimation, Value Improvement Practices, Equipment Specification, Contractor Bid Specification, Constructability Review, Construction Management, and Commissioning.


Peer-review under responsibility of the Scientific Committee of SYMPHOS 2013

*Keywords:* Phosphoric Acid; Phosphate; Fluosilicic Acid; Evaporators, Harrison

## 1. Introduction

This paper seeks to review the essential activities required to reliably complete a project in the phosphate industry. Effective use of these procedures enabled the evaporator expansion project team to successfully design, erect and commission the last four phosphoric acid evaporators (with FSA recovery) to be erected in the United States. The detailed procedures required to complete a major project successfully, along with the documents generated during the course of the project fill many volumes. Only an overview is provided in this paper due to space limitations. Additional resource materials are provided in the references for further reference.

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Peer-review under responsibility of the Scientific Committee of SYMPHOS 2013
doi:10.1016/j.proeng.2014.09.079

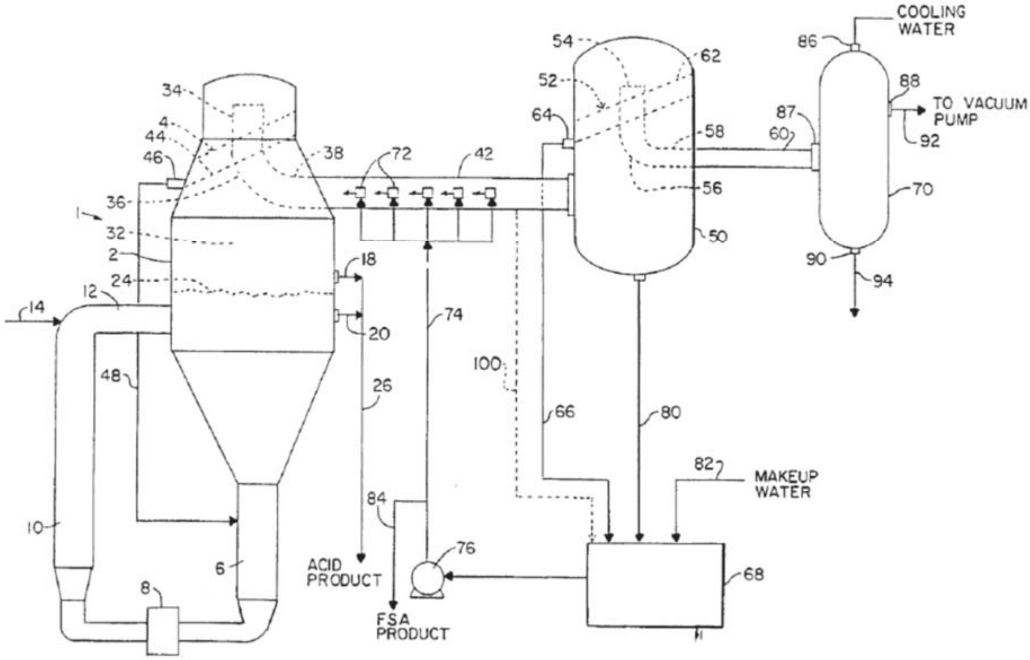


FIG. 1

Figure 1 – Evaporator with FSA recovery system [1]

Figure 1 depicts the basic evaporator and fluosilicic acid recovery system that can be delivered for industrial use. The evaporator design has an integral entrainment separator to minimize acid losses to the condenser. The fluosilicic acid (FSA) recovery system involves recirculating the FSA solution while also removing a portion of the solution as product. Condenser systems can operate with open or closed circuit cooling water. Non-condensable vapour removal can be provided with a vacuum pump, or steam ejector.

**Nomenclature**

| | |
|---|---|
| FSA | Fluosilicic Acid |
| FEL | Front End Loading |
| PSD | Project Scope Definition |
| VIP | Value Improvement Practice |

## 2. Project Objectives

Project objectives can include determinations of items such as the production capacity of a new unit, the products(s) to be manufactured, and the financial performance criteria required by the owner. Project objectives are frequently documented in the invitation to bid documents, when firms are bidding for the engineering work. However, some project objectives may be established later, perhaps after a comparison of the economics for multiple product alternatives during a pre-feasibility study.

## 3. Project Stages / Front End Loading (FEL)

A properly engineered installation frequently requires completion of four separate projects. The early project stages seek to value the project and compare alternatives. The later project stages work to optimize the detailed design of the selected alternative. The most common stages used to develop a project, along with typical deliverables are:

| | |
|---|---|
| FEL-1 Pre-Feasibility Study | complete material and energy balances |
| FEL-2 Feasibility Study | equipment list, layout, schedule, +/- 50% estimate |
| FEL-3 Front End Eng. & Design | equipment specs, PIDs, instrument list, +/-30% estimate |
| Detailed Engineering | construction specifications, 3D model, +/- 10% estimate |

## 4. Codes and Standards

Codes and Standards are referenced by the equipment, piping, structural steel and other specifications to assure compliance with quality and design norms. Some frequently referenced standard promulgating authorities include:

| | | |
|---|---|---|
| AACEI | American Association of Cost Engineers Intl. | www.aacei.org |
| AGMA | American Gear Manufacturers Association | www.agma.org |
| AMCA | Air Movement Control Association | www.amca.org |
| CEMA | American Conveyor Equipment Manuf. Assoc. | www.cemanet.org |
| ANSI | American National Standards Institute | www.ansi.org |
| AISC | American Institute of Steel Construction | www.aisc.org |
| ASME | American Society of Mechanical Engineers | www.asme.org |
| ISA | Instrument Society of America | www.isa.org |
| NACE | National Association of Corrosion Engineers Intl. | www.nace.org |
| NFPA | National Fire Protection Association | www.nfpa.org |
| NEMA | National Electrical Manufacturers Association | www.nema.org |
| PIP | Process Industry Practices | www.pip.org |
| PPI | Plastic Pipe Institute | www.plasticpipe.org |
| TEMA | Tubular Exchanger Manufacturers Association | www.tema.org |

## 5. Project Scope Definition & Project Design Basis

One key step is to document and refine the projects scope. Sometimes the client has specific product, process technology and vendor preferences. If so, the scope can quickly be developed and documented as directed by the client. Other times, the available alternatives will be compared using technology and/or financial analysis. Site selection are usually evaluated at this time - including risk analysis due to flooding, earthquake, etc.

## 6. Technology Selection

Multiple technology routes may be available to achieve the stated project objectives in regards to production capacity and product quality. For example, in the manufacture of wet phosphoric acid, two routes predominate, hemihydrate and dihydrate. On some projects the owner will request an economic comparison of the available alternatives. Typically this involves the development of capital and operating cost estimates for the alternatives. Several alternatives may be evaluated, with possible permutations on multiple technologies and/or products. Some examples of process alternatives in the phosphate manufacturing industry include:

Table 1. Process alternatives.

| Area | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|
| Sulfuric Acid | Single Absorbtion | Double Absorbtion | Heat Recovery System |
| Phosacid Route | Wet Process | Dical Process | Pyrometalurgical |
| Wet Phosacid | Hemihydrate | Dihydrate | Dical |
| Gypsum Transport | Slurry | Belt Conveyor | Co-product |
| Product | Rock | Phosacid | DAP/MAP/GTSP |

## 7. Capital Cost Estimation

A project cost estimate is usually produced during each project stage. In the early stages the accuracy may be +/- 50%. As more details are defined in later stages of the project the estimate accuracy is improved. Major considerations in a capital cost estimate include:

Use one or more cost model sources
Use current equipment pricing, bulk material pricing, and local trade rates
Use material take-offs as input for bulk material quantities & installation
Validate estimates against historical benchmarks / reference projects
Account for manpower mobilization and sustenance costs by schedule
Estimate productivity
Standardize work breakdown structure and work packages

## 8. Value Improvement Practices

Front end engineering packages are typically developed in a structured project delivery process system to ensure that they meet all project scope requirements and that stakeholder participation has occurred. The project team facilitates the project delivery process, value improvement practices (VIPs), and applying phase evaluation tools such as the Independent Project Analysis's (IPA) Front End Loading (FEL) Index.

Key activities include the following items:
- Project Management Processes and Planning
- Targeting Project Resources to Maximize Project Performance
- Use of Project Definition Rating Index (PDRI)
- Value Improvement Practice (VIP) Selection, Planning and Implementation
- Implementation of Industry Best Practices
- Documentation of Key Project Activities
- Preparation of Project Execution Plans (PEP) and Procedures

Value improvement practices are deliberate efforts to improve the final project economic performance by refining details in each aspect of the project to minimize or eliminate inefficiencies in the design. Points to consider include: technology selection, classes of plant quality, process simplification, waste minimization, design to capacity, energy optimization modelling, and lifecycle cost analysis.

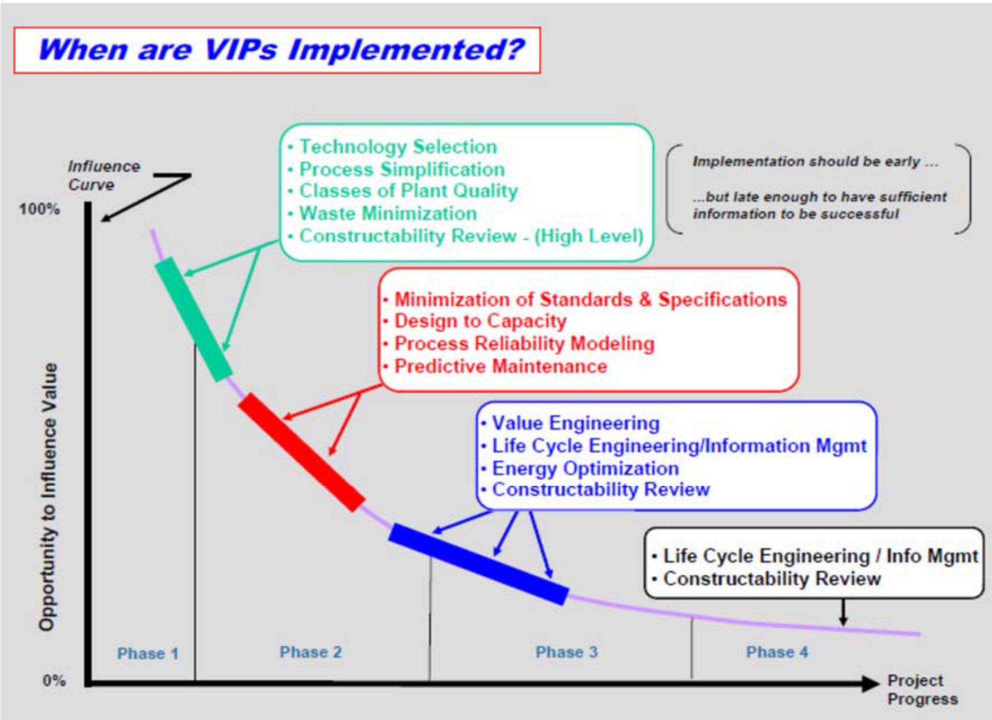


Figure. 2. Opportunity to influence Value

## 9. Equipment Specification

A key milestone in the project management process is receipt of the process equipment bids from the equipment suppliers. In order to reach this milestone two things must happen. A list of bidders must be established, and specifications for the required process equipment must be prepared. A typical set of specifications issued to an equipment vendor for bid includes:
- Equipment specification
- Motor specification
- Noise specification
- Welding specification Material specification
- Painting Specification

## 10. Contractor Bid Specification

One of the critical deliverables for the project management team is the delivery of comprehensive bid documents for issuance with the request for bid tenders for the erection contractors. These documents typically include:

- Equipment list
- Equipment location drawings
- Piping and instrumentation drawings
- Piping isometric drawings and piping plan drawings
- Piping specifications
- Insulation specifications
- Paint specifications
- Welding specification

## 11. Model and Constructability Reviews using 3D CAD

On most jobs either one or two 3D model reviews are conducted as part of the client approval process. Typically these are held when engineering is 30% complete, and again when 70% complete. 3D model reviews are one of the best tools to allow the project team to review the following items:

- equipment locations,
- pipe and conveyor routes
- access to operate and maintain equipment
- construction sequence / constructability
- drainage and cleaning infrastructure

Frequently the design is refined based on both engineer and owner comments during the model review process. The model reviews provide the entire team with an accurate 3D vision of the project while it is being designed, thereby assisting the team to make valuable layout improvements and refinements at an earlier stage. This process helps to minimize later modifications.

## 12. Construction Management

Activities in construction management include:

- Plan, organize and direct field work
- Establish field office
- Direct field procurement activity and review & approve all expenditures
- Maintain project schedule by assuring timely completion of milestones
- Control project budget
- Administer project subcontracts
- Assure compliance with quality control protocols
- Make required staffing decisions & supervise staff
- Maintain effective communication and reporting

## 13. Commissioning

The most important part of commissioning begins before mechanical completion with operator training. A successful project requires that the operations team be fully briefed on all aspects of operation of the new equipment. Once mechanical completion for the project is complete, the commissioning team can then coordinate the initial operations. Three phases of commissioning can be divided into pre-construction or outage work, construction and/or outage, and close-out/demobilization.
Key commissioning activities include:

- Hazard study and mitigations
- System cleaning protocols
- Punch lists by equipment system or line
- Alarm action list
- Mechanical contractor authorization to commence commissioning by system
- Leak test procedure checklist and procedure
- Instrumentation test and evaluation protocol
- DCS system test protocol
- Motor run test and rotation check log

- Interlock test log
- Emergency shutdown interlock test log
- Chemical inventorying safety checklist
- Relief system evaluation log
- Critical insulation inspection and verification log
- Critical gasket installation checks & bolt torque logs
- Lubrication first fill and check list
- Pre start-up safety review prior to introduction of hazardous chemicals
- Authorization to introduce hazardous chemicals certificate & checklist
- Commissioning procedures
- Standard operating procedures
- Certificate of completion of commissioning to owner/operator

## 14. Project Performance Metrics

Seven criteria can be used to track the performance of a project:

- Actual Safety Performance vs. Zero Incidents
- Mechanical Completion vs. Scheduled Completion
- Actual Spending vs. Budgeted Spending
- Final Scope vs. Original Scope
- Actual Annual Production vs. Design Capacity
- Actual Quality vs. Product Requirements
- Actual Financial Performance vs. Expenditure Authorization Basis

## 15. Lessons Learned

Lessons may be learned from the problems experienced with prior projects. Unfortunately, several major recent phosphate projects have underperformed the financial, schedule, and production performance expected by their initial owners. Suffice it to say here that in many instances the engineering companies have met their revenue objectives when building these projects, while the new phosphate plant owners have frequently struggled to meet their revenue targets.

One metric that can be used to evaluate project success is the time from start-up until annual production exceeds 90% of nameplate. WMC started-up in late 1999, but the annual production did not exceed 90% until 2003 [6]. IFFCO Paradip's sulphuric acid plant has reportedly achieved a record 82% utilization (2010/11) after 10 years of operations, breaking the previous record of 62% [7]. How long will it take for new plants such as TIFERT, JIFCO & Ma'aden to reach 90% of annual capacity?

What are the major causes for phosphate projects to under-perform? One of the key shortcomings appears to be failure to retain qualified staff with specific phosphate experience. It is hard to understand why an owner would allow an engineering company to design and manage a project with a team with little to no prior experience in the phosphate business.

A basic fact is that the phosphate industry has historically been centred in a few specific locales such as Florida and Morocco. It is no surprise that many of the human resources knowledgeable about the industry are also found in these locations. Curiously, the location selected as the centre for the engineering effort on many recent major phosphate projects is frequently remote from those knowledgeable about the industry.

Will the engineering company with the major award be forced to proceed primarily with human resources that have never had the opportunity to work on a phosphate project before? Many of the people with industry specific experience are already gainfully employed in Tampa or Casablanca working on competitors' phosphate projects and have no real incentive to relocate for a one time project. This situation does not appear to be in the owner's best interest, but it is a recurring scenario.

## 15. Team Qualifications & Selection

Ideally the team assembled to work on your next phosphate project will have significant prior experience, where their clients achieved desired project objectives. Be sure to quantify the years experience in the phosphate industry when next making project staffing decisions. If the bids for the engineering are competitive, it might be best to select an engineering company with a history of successful projects.

## 16. Conclusions

Projects in the phosphate industry can be executed on schedule and on budget with zero safety incidents. Equally important, rising global per capita GDP, combined with steadily increasing population will provide ample demand for phosphate fertilizers.

In addition to this built-in demand growth - possible curtailments in phosphate project investment in China (now that self-sufficiency has been obtained) and/or flooding of low lying (<20 meters) producers may cause acute demand for new capacity. These factors will contribute to significant future investment in the phosphate industry. Please help to minimize waste, downtime, and poor project performance by demanding a qualified team that has phosphate experience when you next tender bids for a project in the phosphate industry.

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